**Correctness of calculation of MPN penalty in SM model: Do We Need Correction to Account for The ISI Penalty**

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As an action item from the MMF Ad Hoc, I was tasked to perform a check on the correctness of the calculation of the MPN penalty and the need for a correction to account for the effect of the ISI. To achieve and simplify the analysis I modified the spreadsheet to, setting a number of parameters to low values, so that their penalties are 0. This applied to: RIN (-160dB/Hz), deterministic jitter and DCD\_DJ (both set to 0 ps), modal noise penalty (0 dB) and baseline wander (0). The rise-fall time was set to 19ps.

The receiver sensitivity was set to -10dBm and connector loss to 0. TX power was initially set to -6.4dBm, to give us 3.6 dB power budget. We are left with the fiber loss (at 100m 0.36 dB), ISI penalty (2.96 dB) and MPN penalty (0.31 dB) consuming the entire power budget. This first case is without making changes to the MPN penalty due to ISI. However, if we make a change to address the ISI, the MPN penalty rises to 1.58 dB, leaving us with a negative margin of 1.3 dB.

To check which one is correct, we also perform the actual calculation, without resorting to penalties, rather calculating the BER directly.

We first find the receiver noise SD from the nominal receiver sensitivity, then the MPN SD at the receiver (and multiply MPN SD by the OMA to remove the normalization). The total SD is found using rms addition.

To find the worst case BER, we use the standard formula:



In the above expression TXOMA is the TX OMa in dBm. Running the actual numbers we get the following:

RX OMA sens = -10dBm; RXOMAsd = 0.0142/2 = 0.0071;

RXOMA = 0.2109;

MPNSD\_normalized = 0.052 (from spreadsheet), MPNSD = 0.0110 /2 = 0.00550;

SDtotal = 0.0179/2 = 0.0090;

dmin = 0.1067/2 = 0.0533;

BER = 1.39e-9;

Obviously, this is not what the SM model predicted (to get BER = 1e-12), since it told us we would have exactly 0 dB margin. Instead, we got BER = 1.39 e-9, meaning we have negative margin.

We now check if we get a correct result by making the correction (which takes into account the ISI). Now the model tells us that we are running 1.3dB negative margin. So, we now change in the spreadsheet the TX OMA to -5.1 dBm (power budget of 4.9dB) giving us 0 margin with the corrected formula. We now re-run the above calculation, with TX OMA = -5.1 dBm and got the following numbers:

RX sens = -10dBm; RXsd = 0.0142 = 0.0071;

RXOMA = 0.2844;

MPNSD\_normalized = 0.052 (from spreadsheet), MPNSD = 0.0148 = 0.074;

SDtotal = 0.0205 / 2 = 0.0103;

dmin = 0.1439/2 = 0.0719;

BER = 1.14e-12;

With the correction applied, we got BER = 1.14e-12, corresponding to 0 dB margin, which is what we expected. The conclusion: with the correction applied, both approaches give the same result.

Therefore, I think we need to change the calculation of the MPN penalty to account for the ISI, similar to the handling of the RIN.